



Beam stability and quality in the presence of beam beam and transverse damper

X. Buffat, S. Antipov, J. Barranco*, L. Barraud, E. Métral,
T. Pieloni*, C. Tambasco*



Many thanks to D. Valuch and the ADT team

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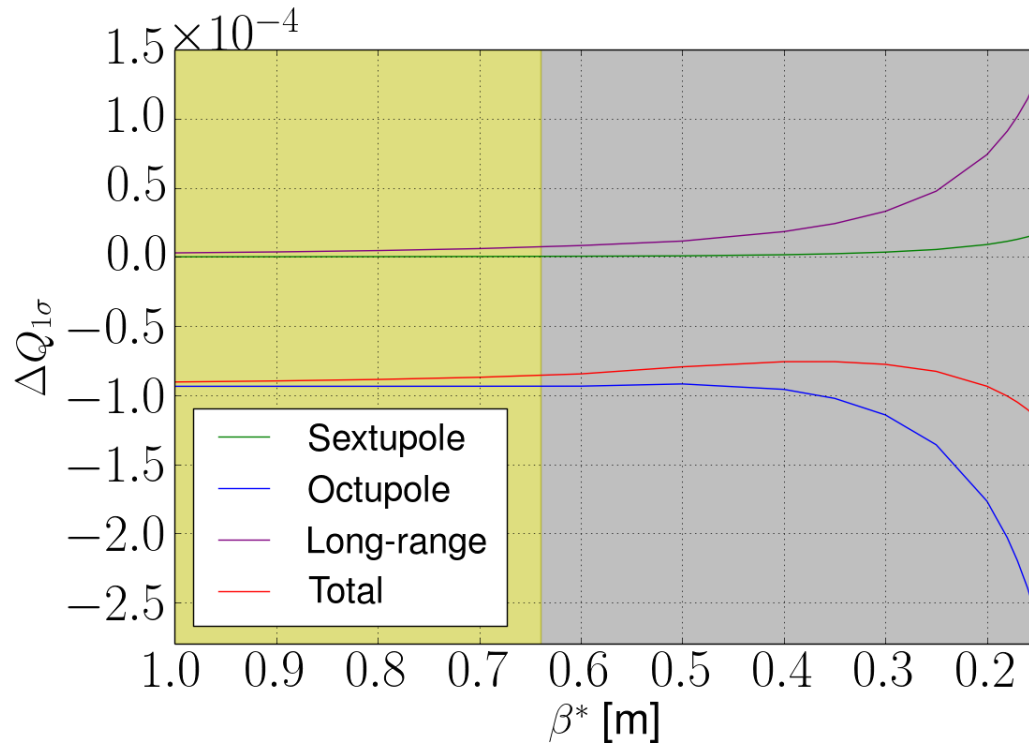


HL-LHC collaboration meeting – 15.11.2017

Content

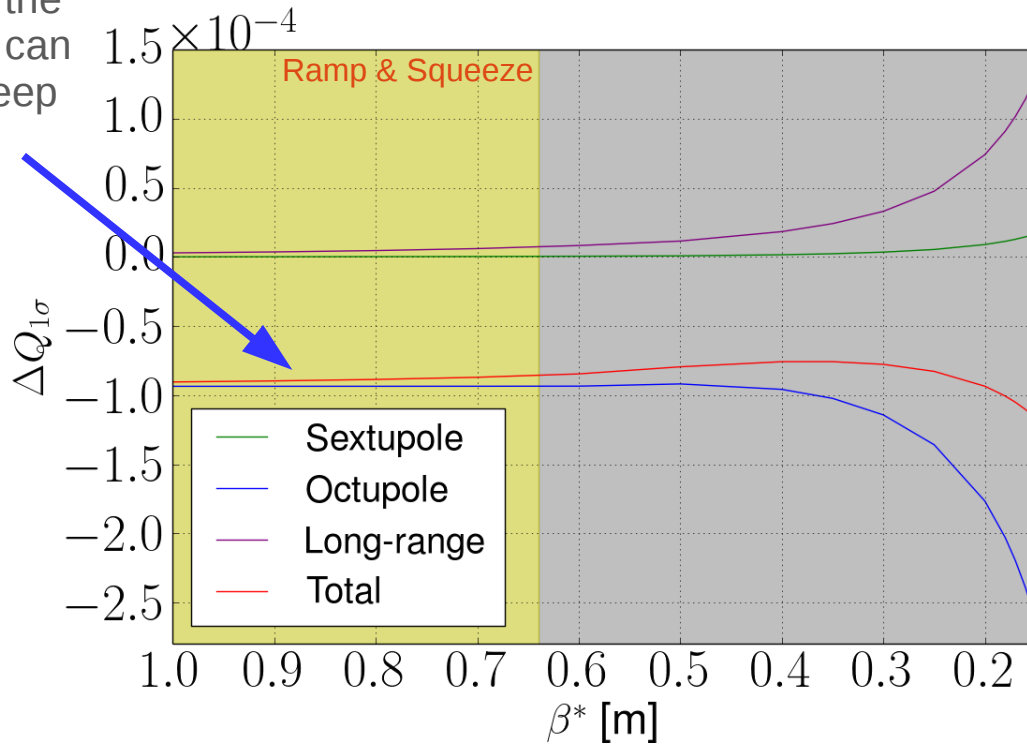
- Landau damping of head-tail modes at top energy
 - Baseline
 - Ultimate BCMS / 8b4e
- Modelling of the mode coupling instability of colliding beams
- Noise, decoherence and emittance growth
- Summary

Tune spread through the HL-LHC cycle – Baseline



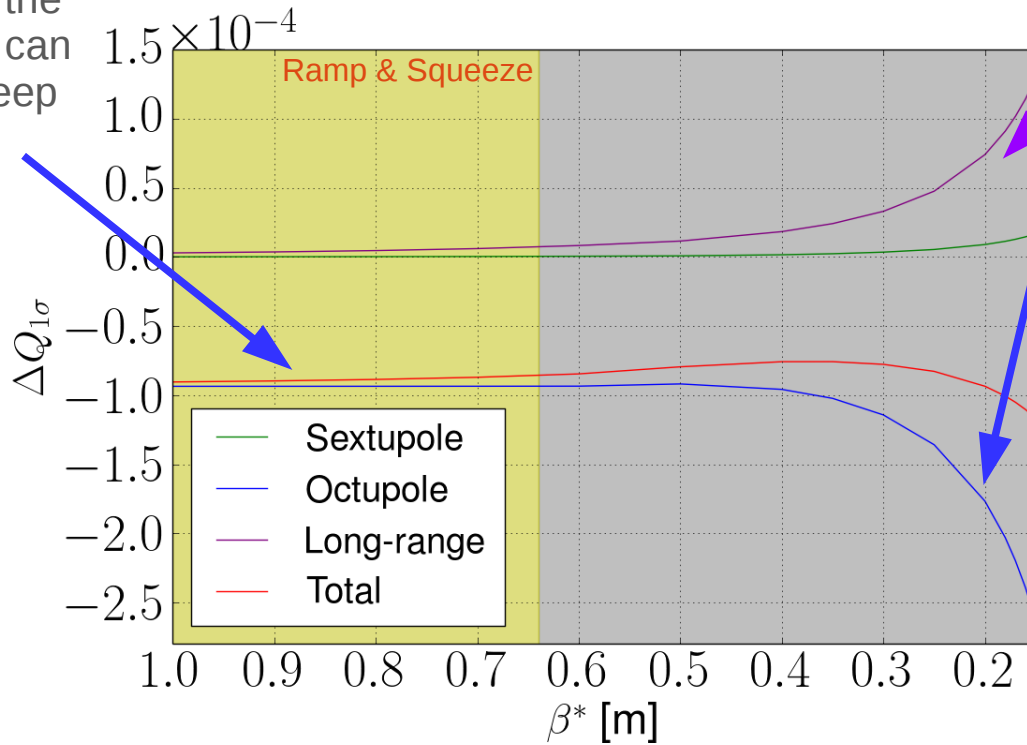
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- During the ramp the octupole current can be adjusted to keep the tune spread constant



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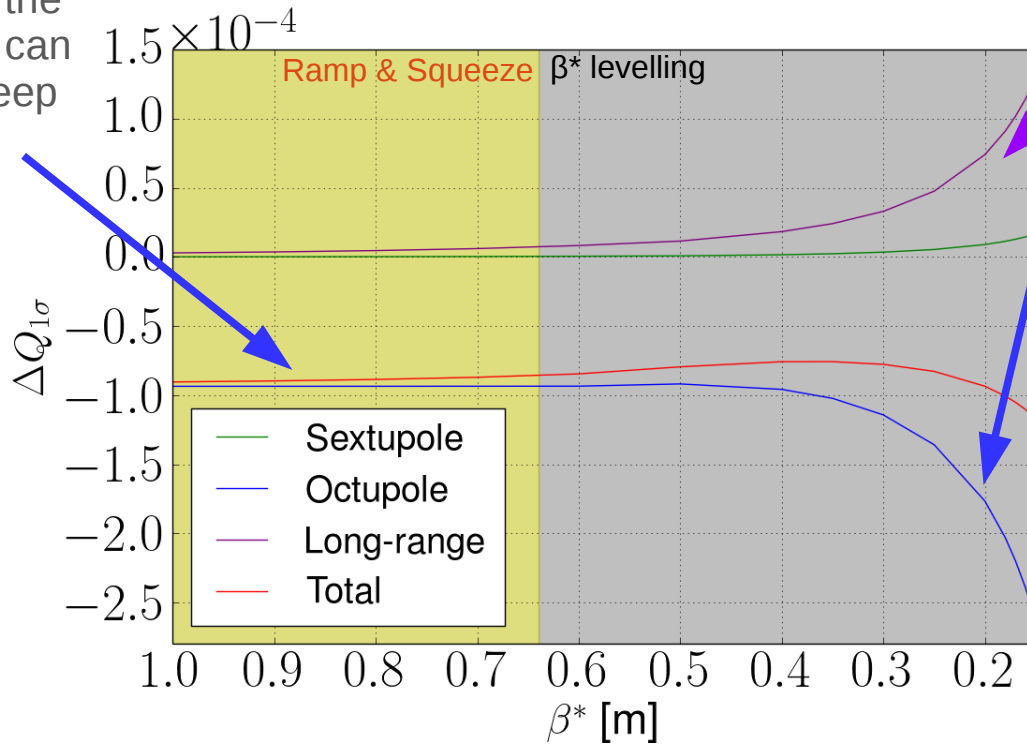
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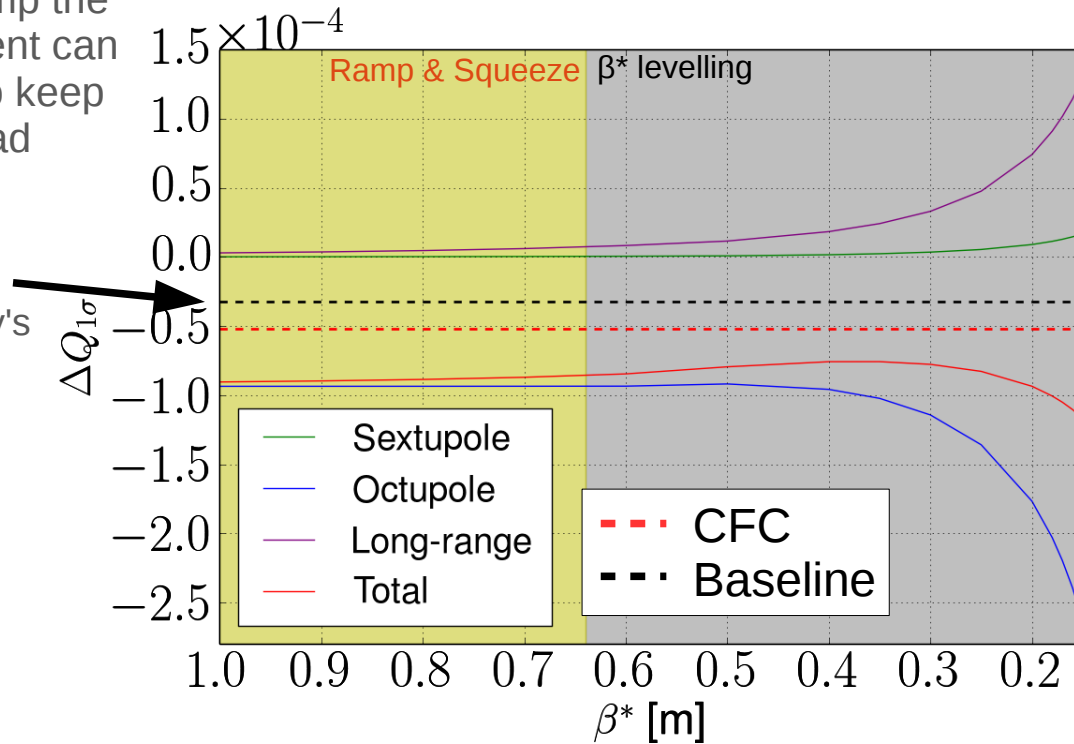
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- Thanks to β^* levelling, the low β^* are reached with colliding beams \rightarrow dominated by head-on beam-beam tune spread

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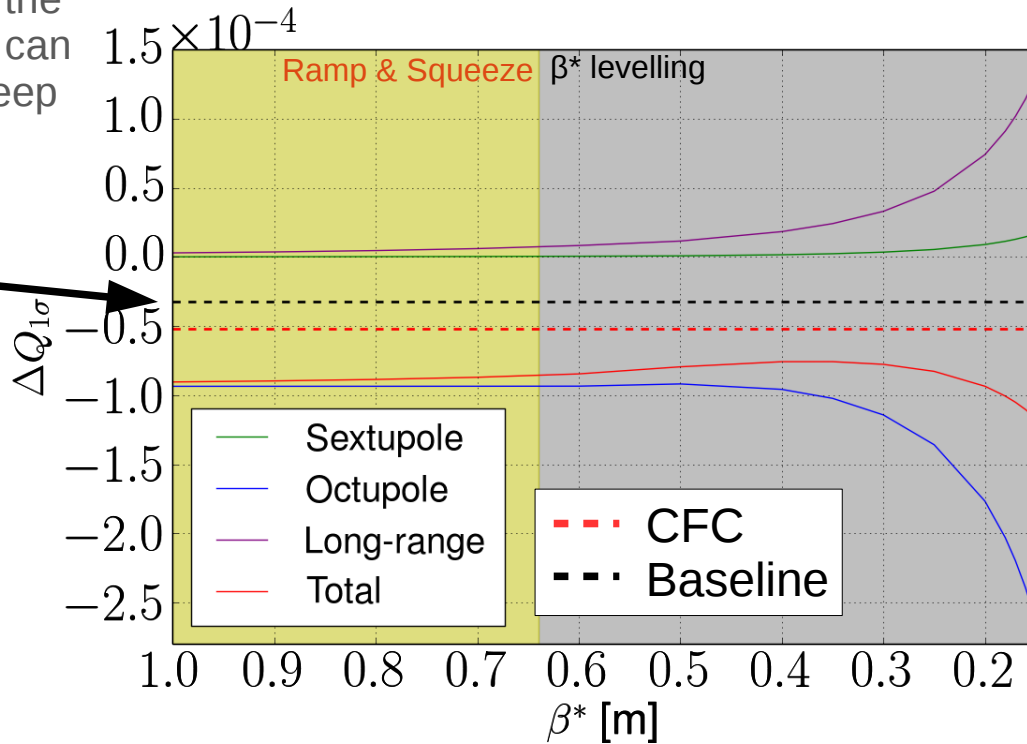
- › During the ramp the octupole current can be adjusted to keep the tune spread constant
- › Minimum requirement (See S. Antipov's talk)



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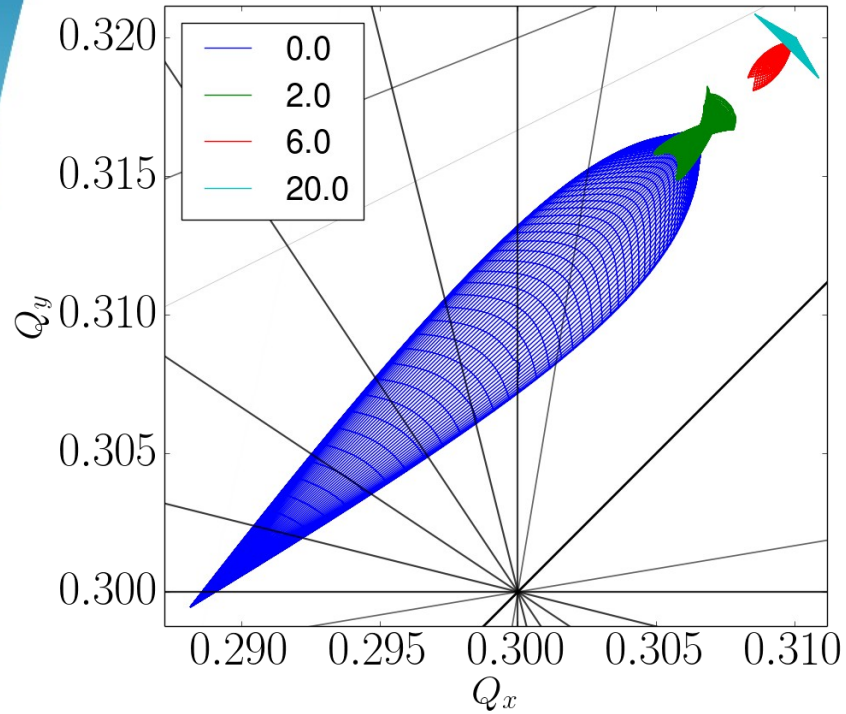
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- › During the ramp the octupole current can be adjusted to keep the tune spread constant
- › Minimum requirement (See S. Antipov's talk)
- › The tune spread is sufficient to ensure the beam stability during the ramp and squeeze, even without replacing the collimators

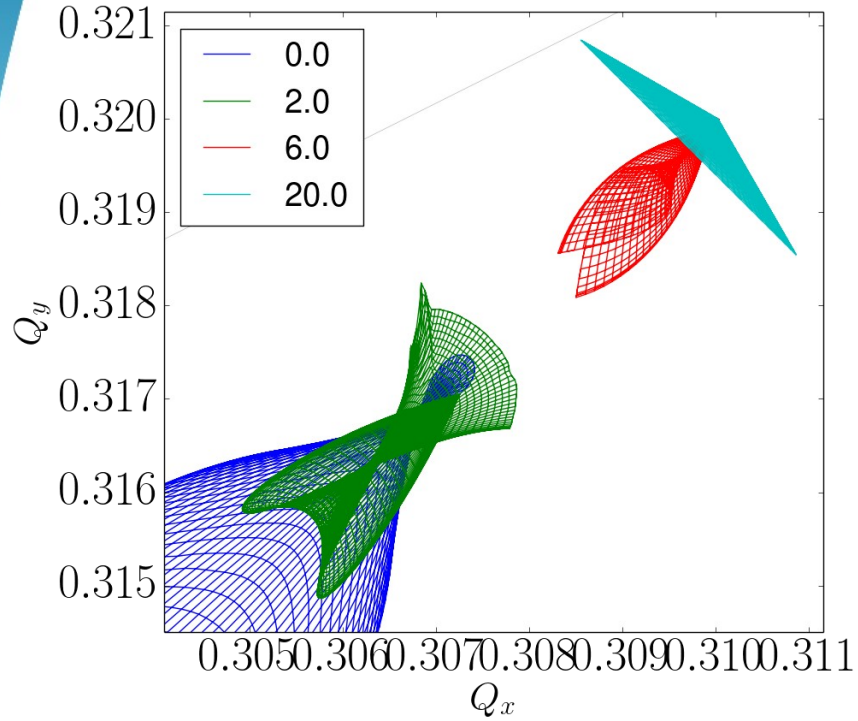


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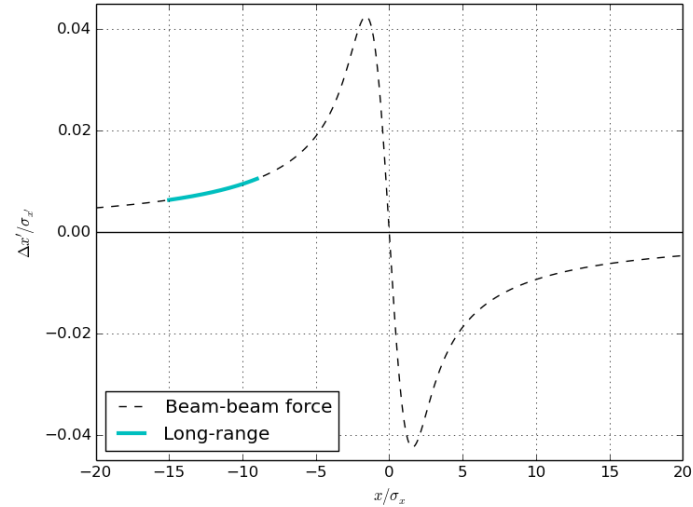
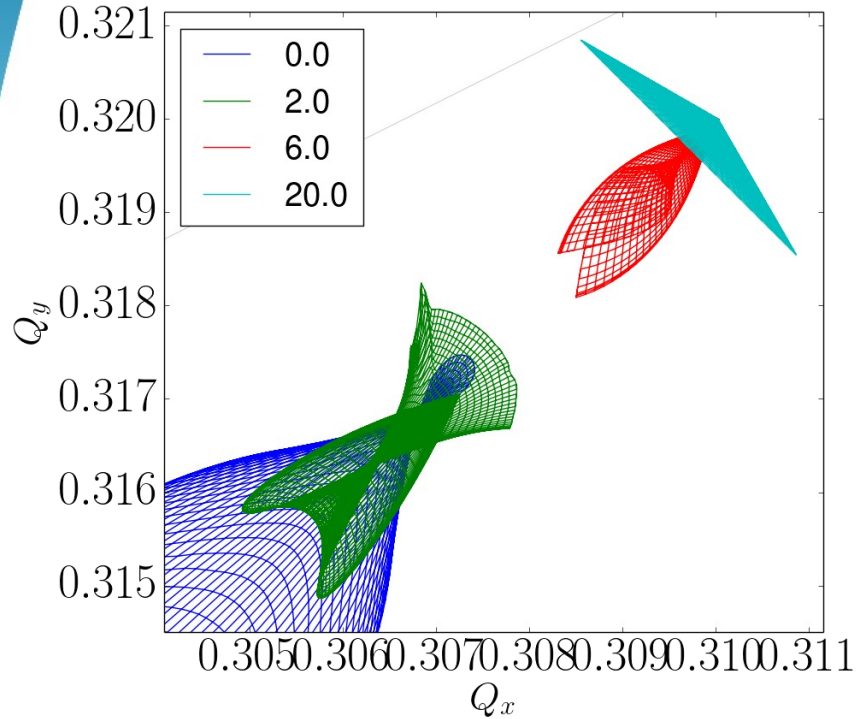
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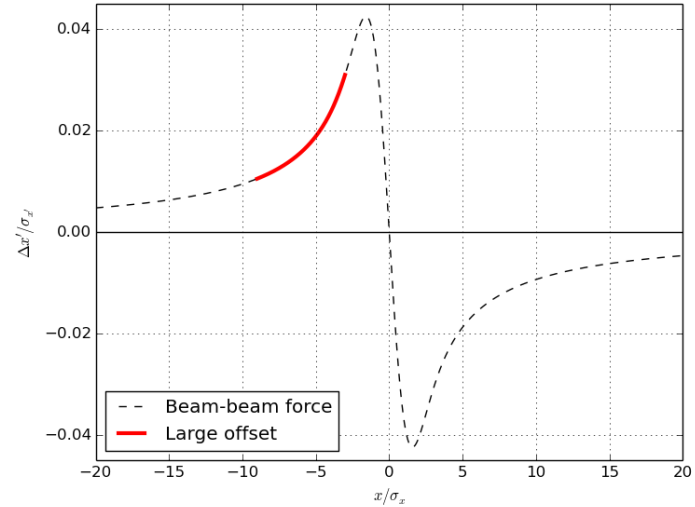
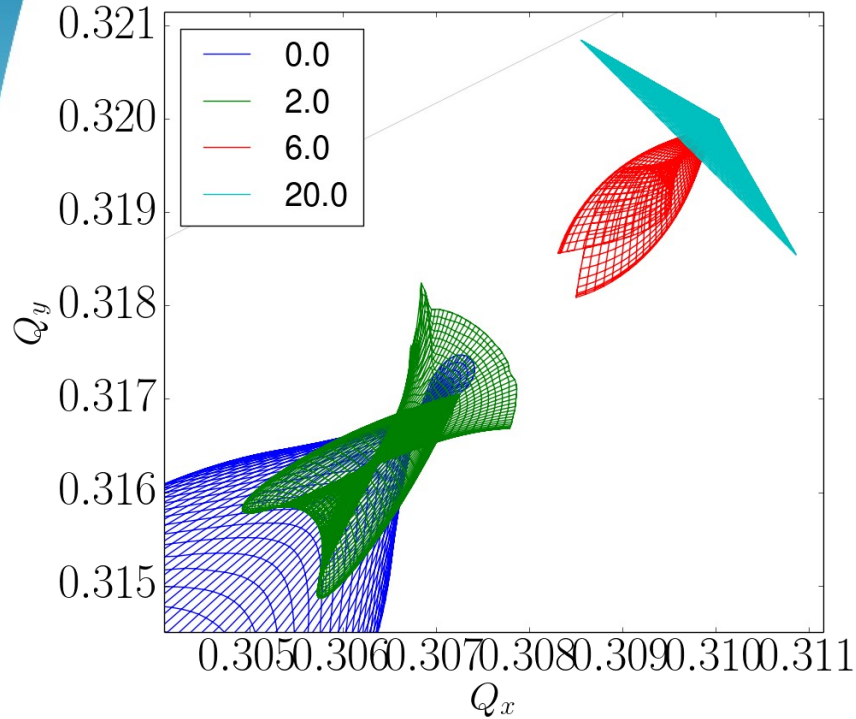


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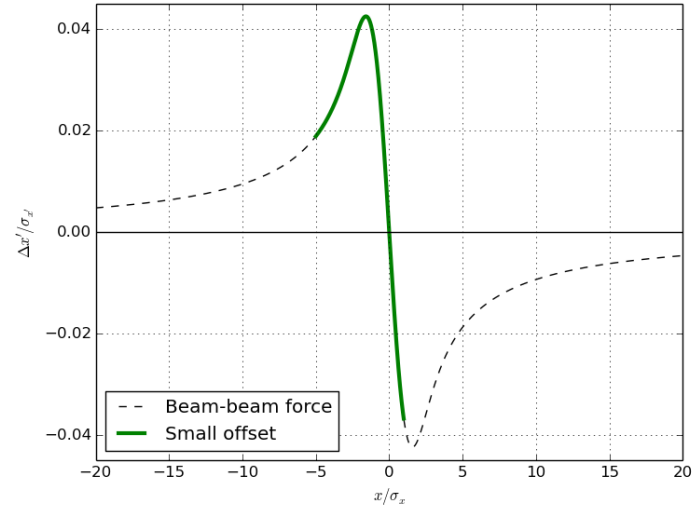
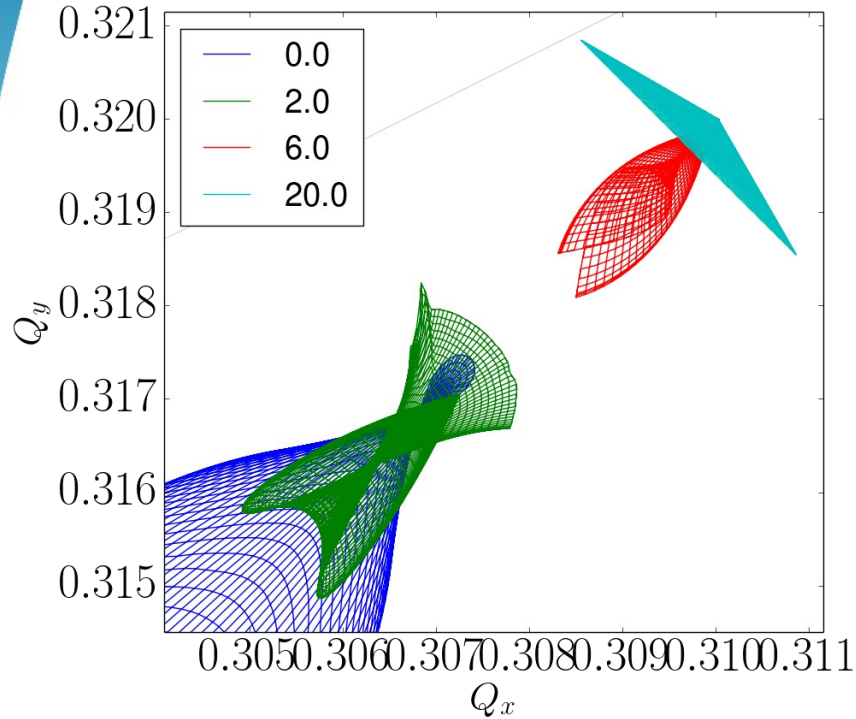
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- Towards the end of the process the footprint becomes dominated by the interaction at the IP (offset, then head-on)

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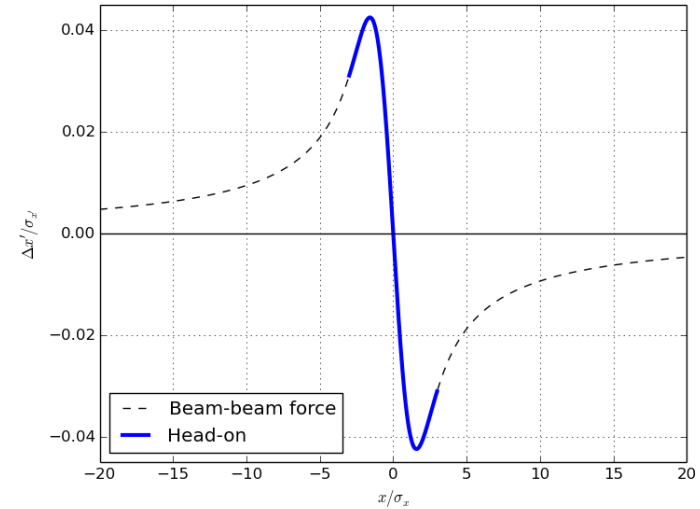
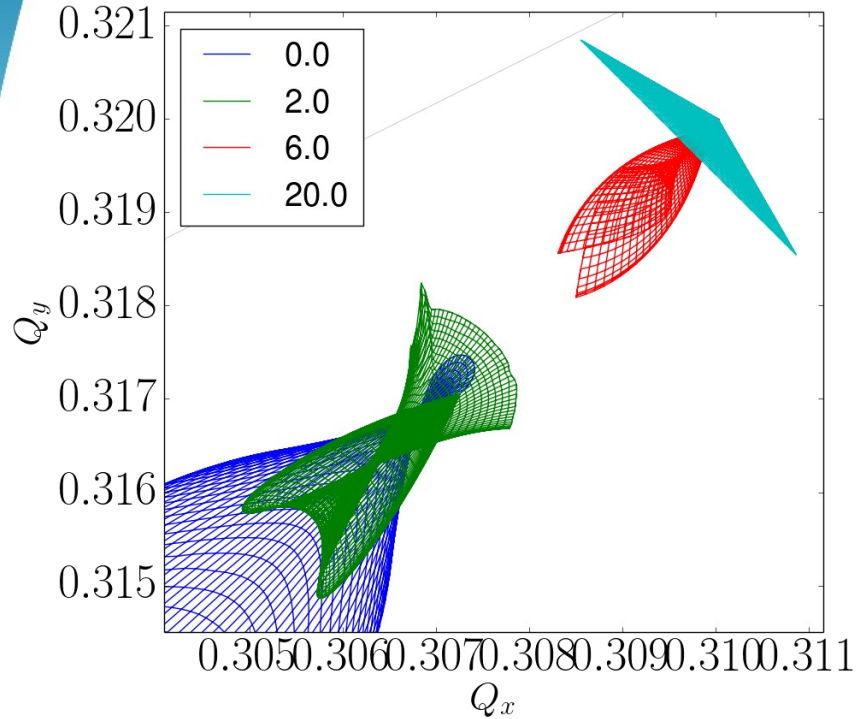
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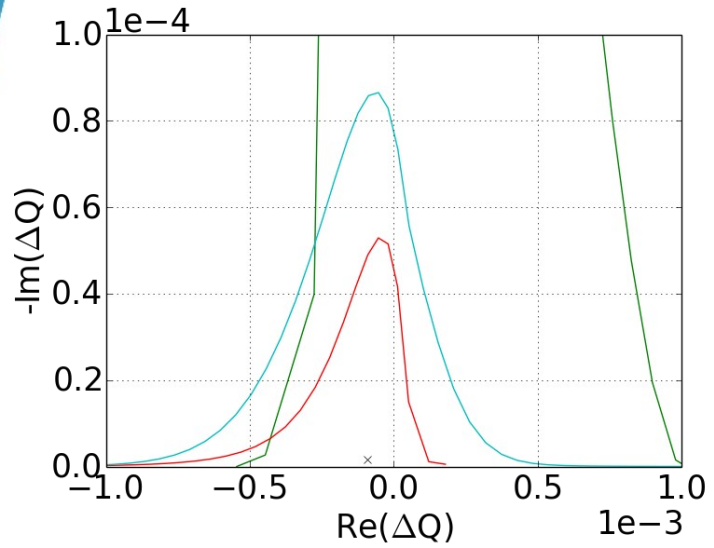
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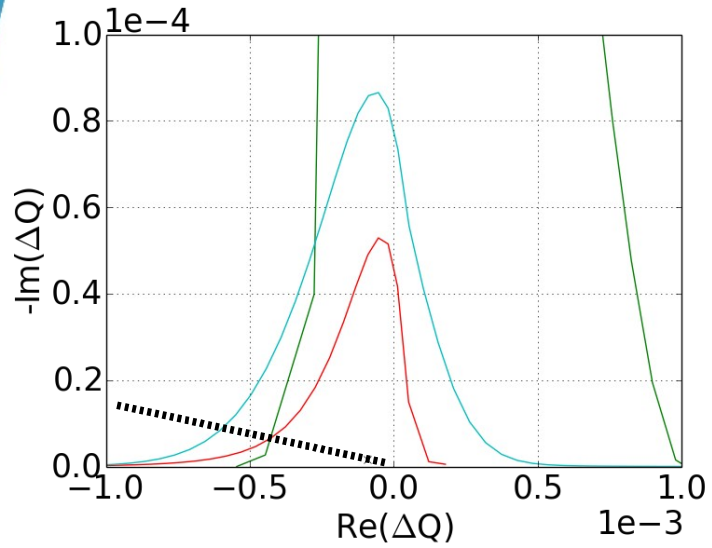


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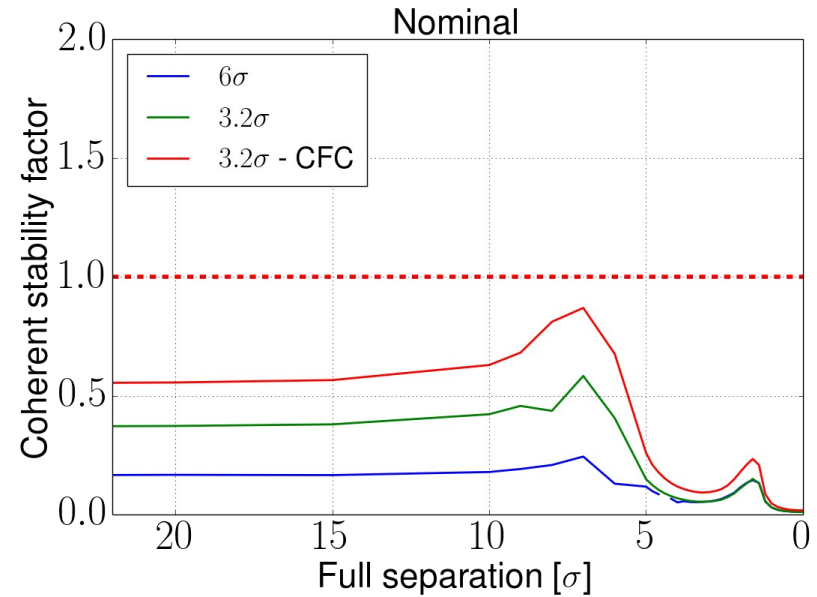
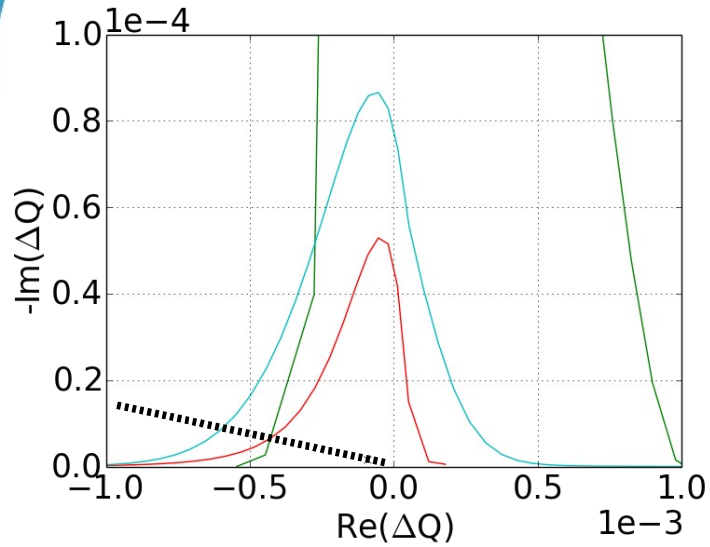
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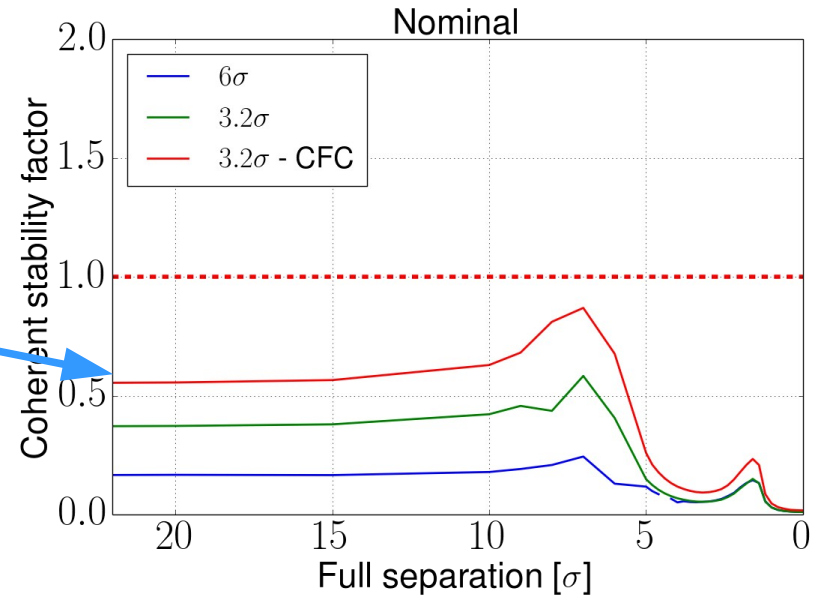
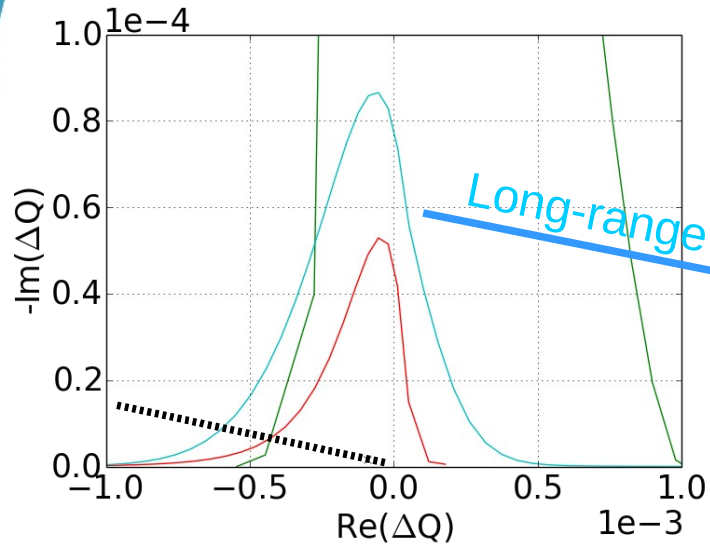
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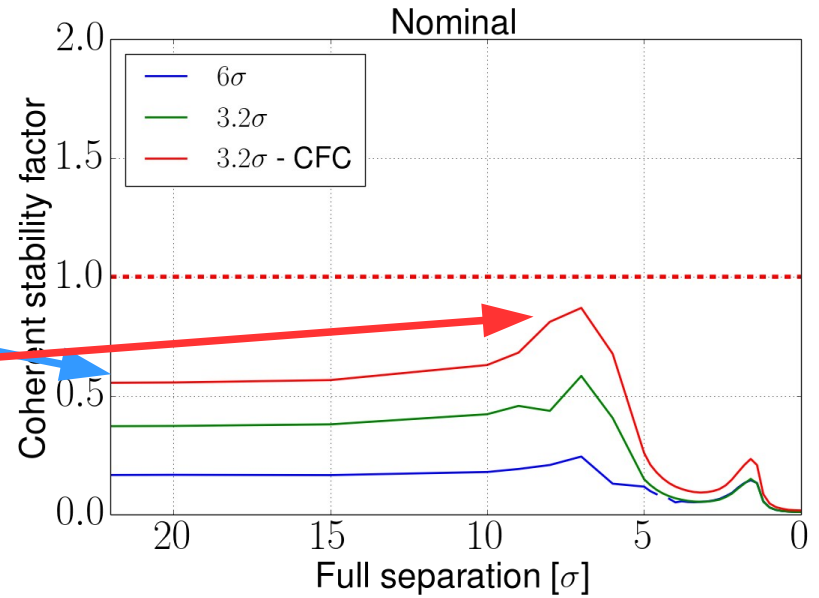
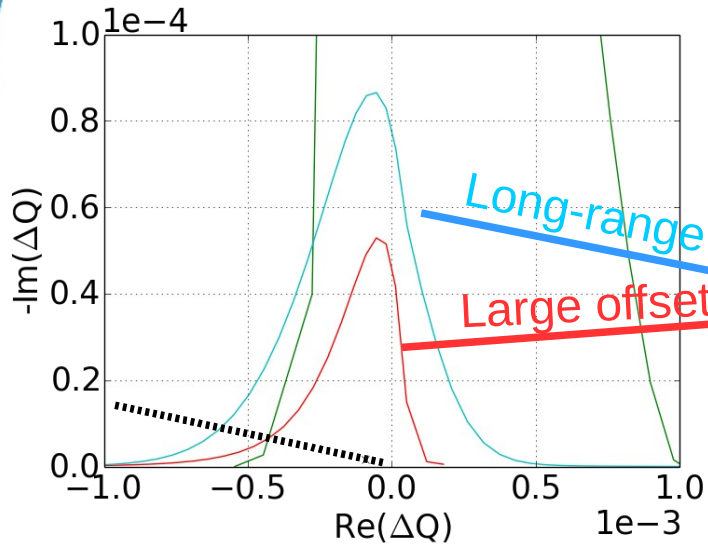
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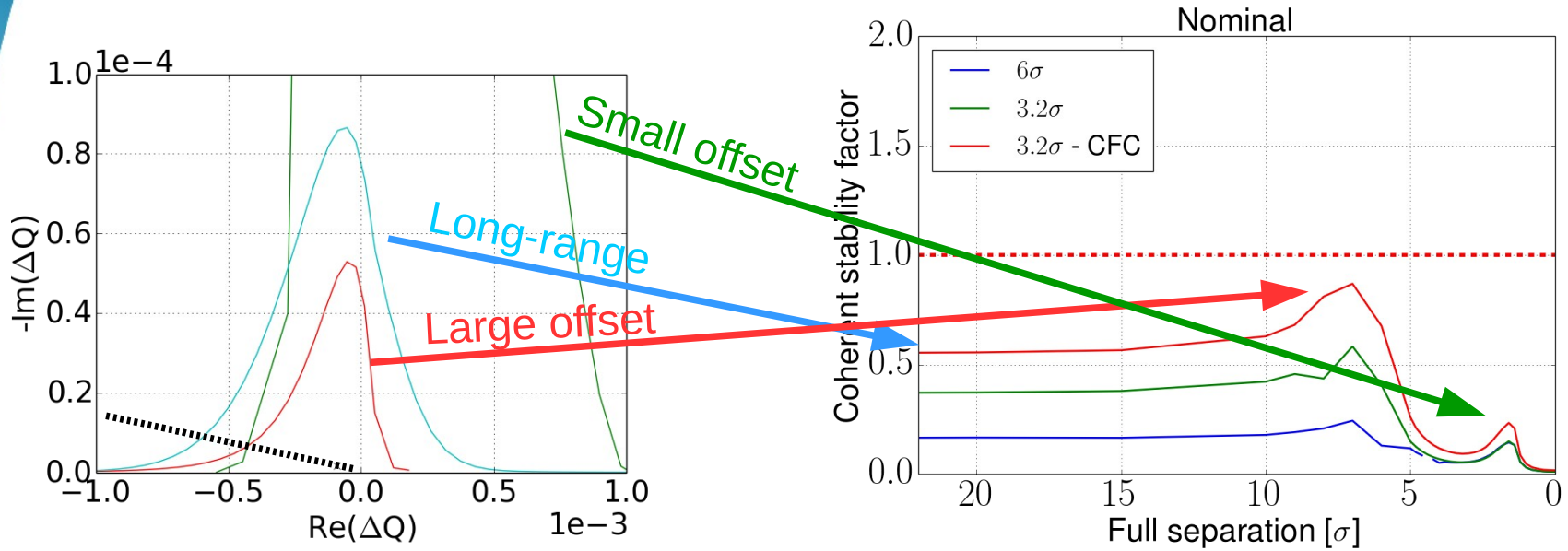
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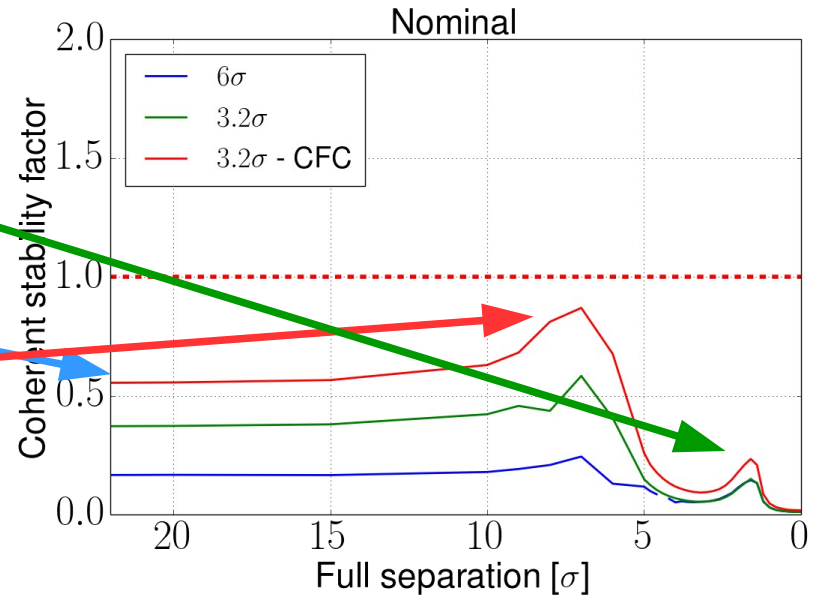
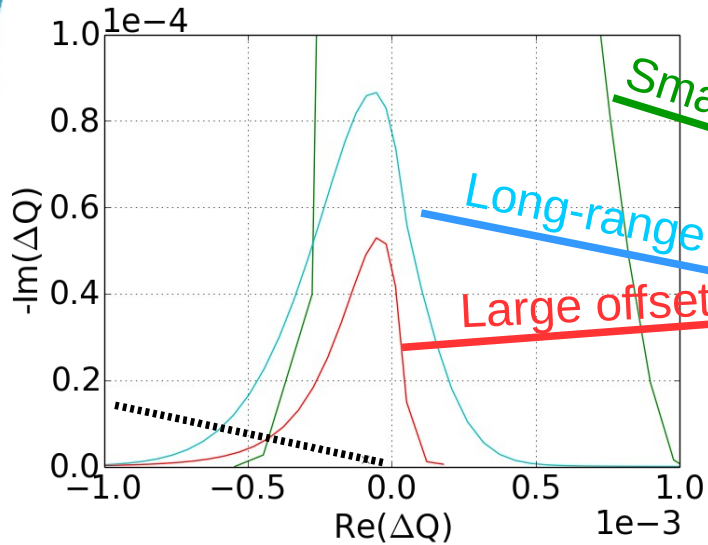
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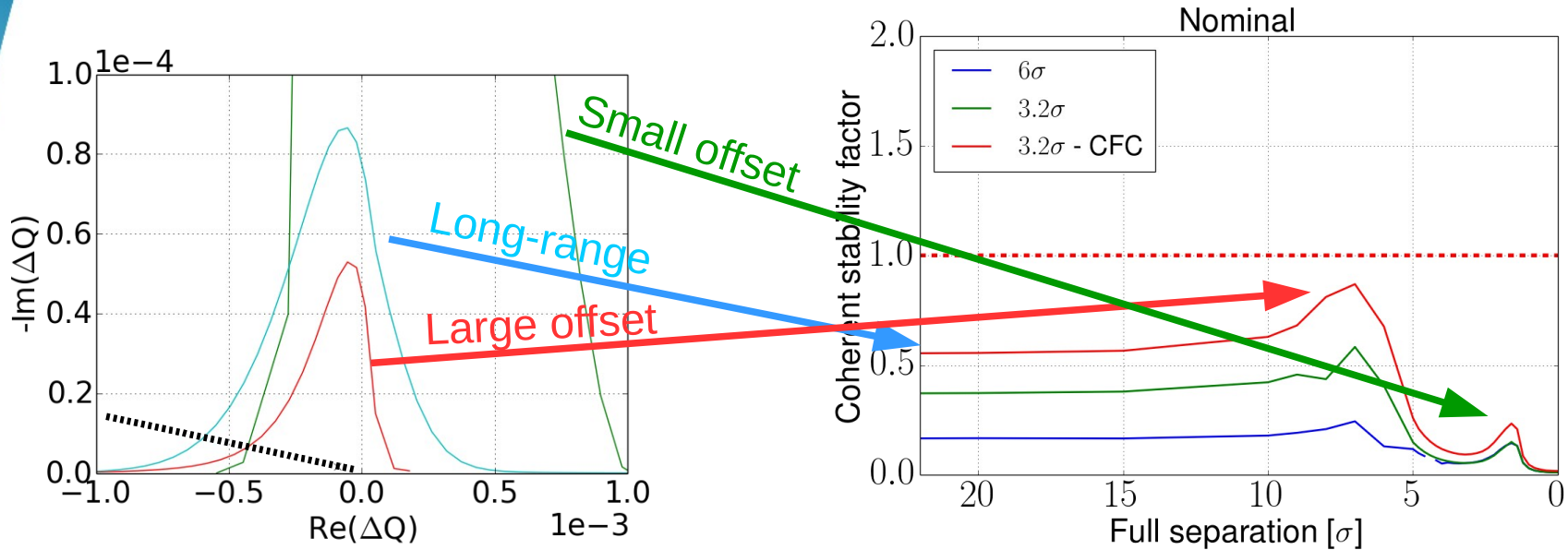
Tune spread through the HL-LHC cycle – Baseline



Two minimums of stability are reached when collapsing the separation between the beams at the IP

– Neither are critical in the baseline scenario

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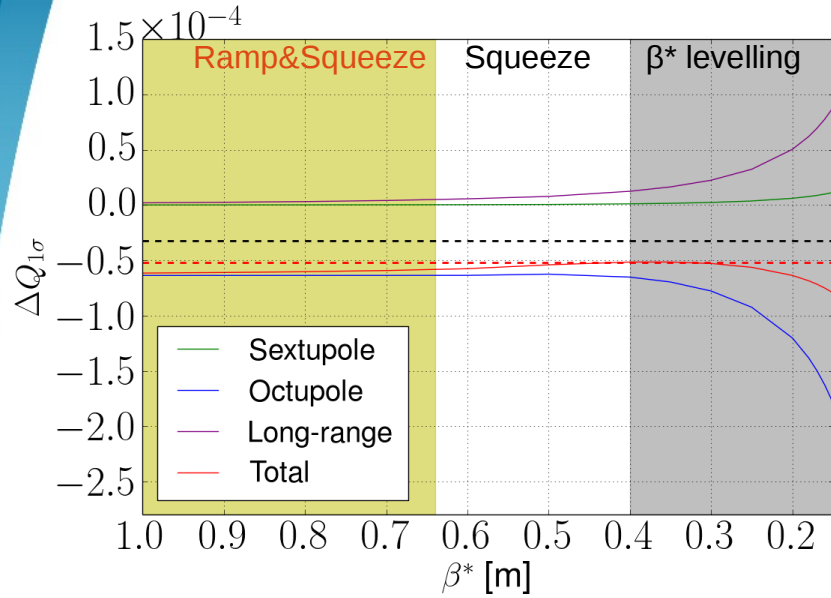
– Neither are critical in the baseline scenario

The second minimum is strongly reduced w.r.t the LHC thanks to the larger beam-beam tune shift

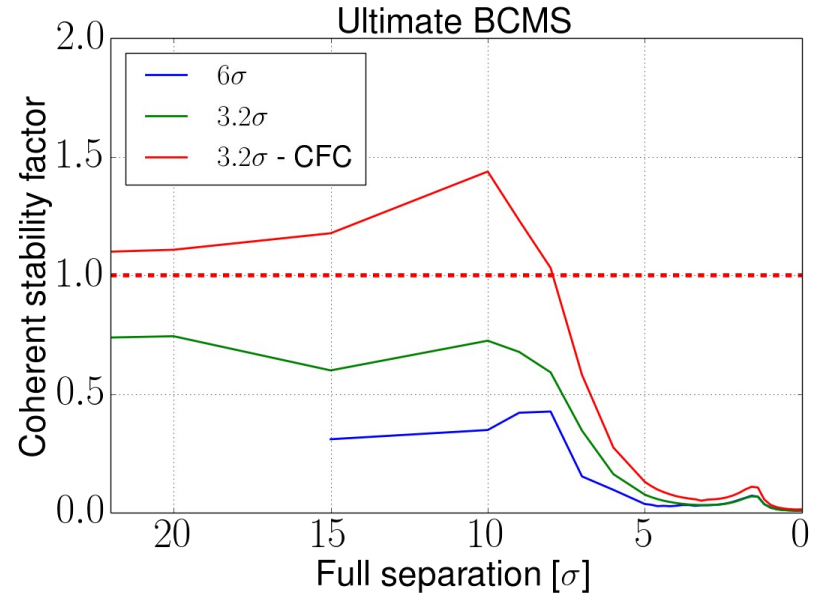
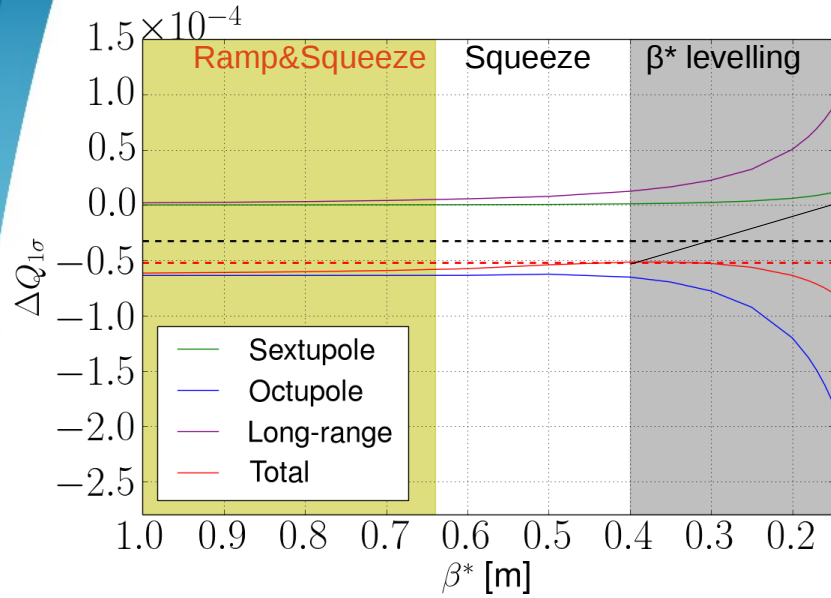
→ CC should be on when collapsing the bump to profit from this effect

→ No instabilities are expected with small transverse offsets (e.g. fine adjustment of the luminosity) in this configuration

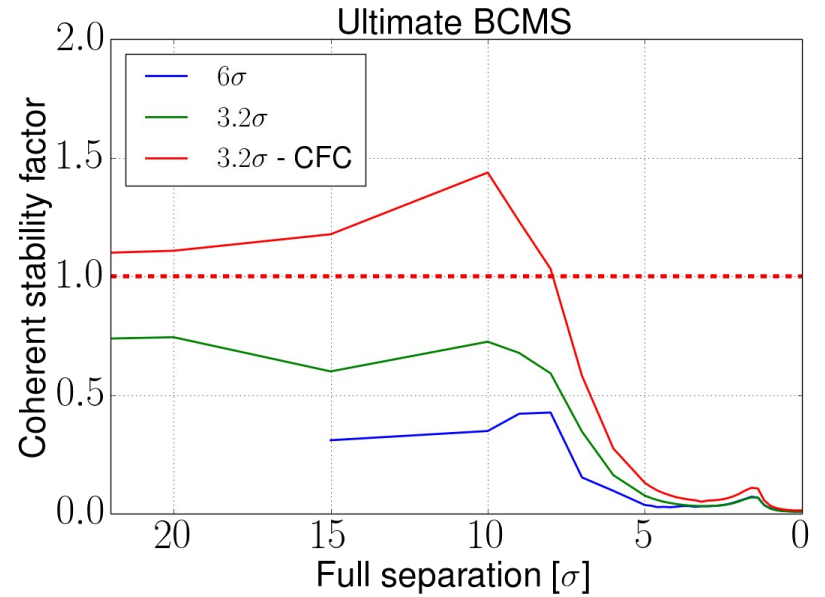
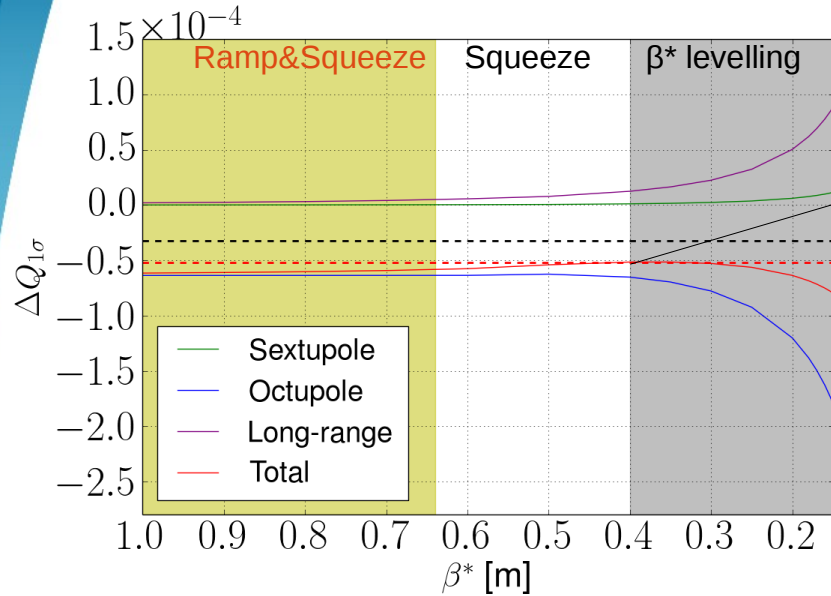
Tune spread through the HL-LHC cycle – Ultimate BCMS / 8b4e



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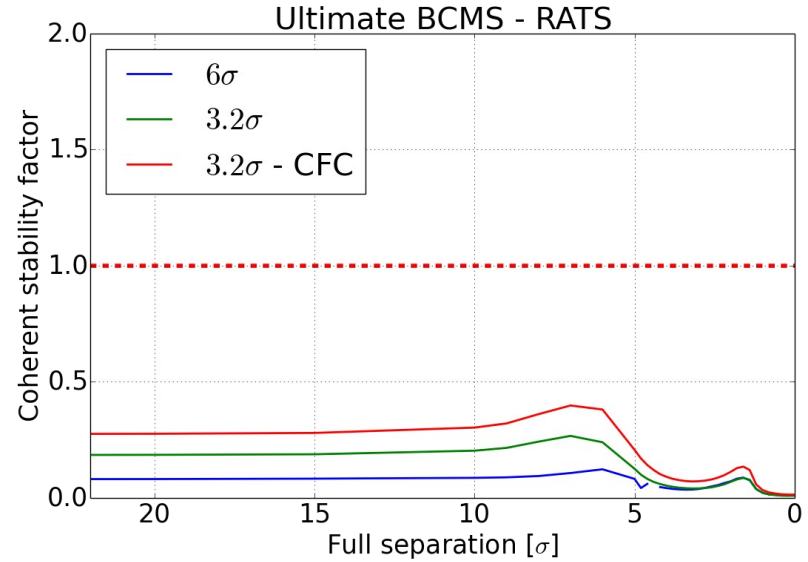
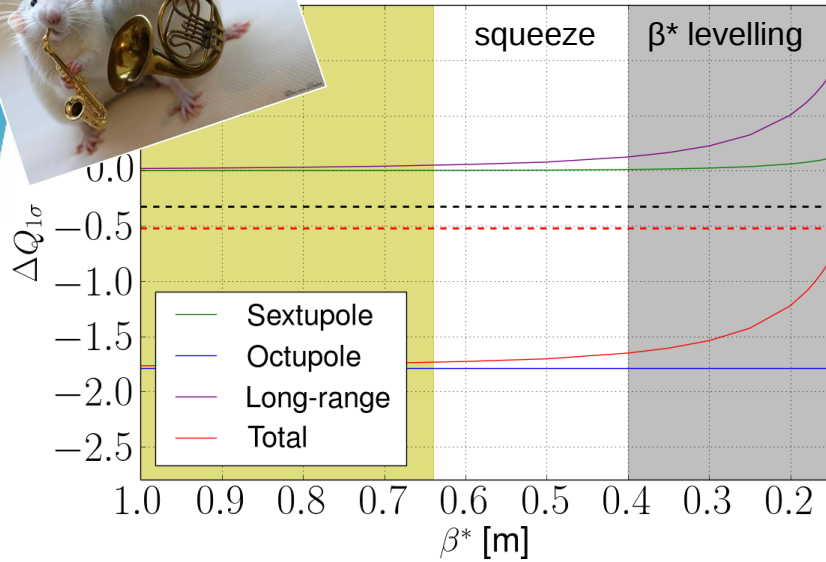
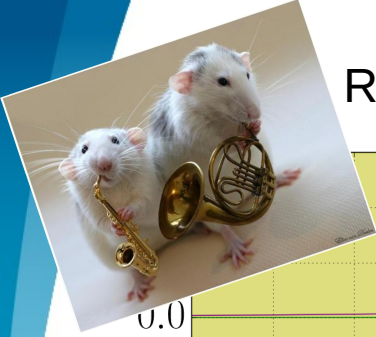


Tune spread through the HL-LHC cycle – Ultimate BCMS / 8b4e



- The ultimate scenario with BCMS/8b4e beams is possible only with the upgrade of the collimators with low resistivity material (Mo+MoGR)
 - Despite the collimator upgrade, the stability margins remains above 0.5

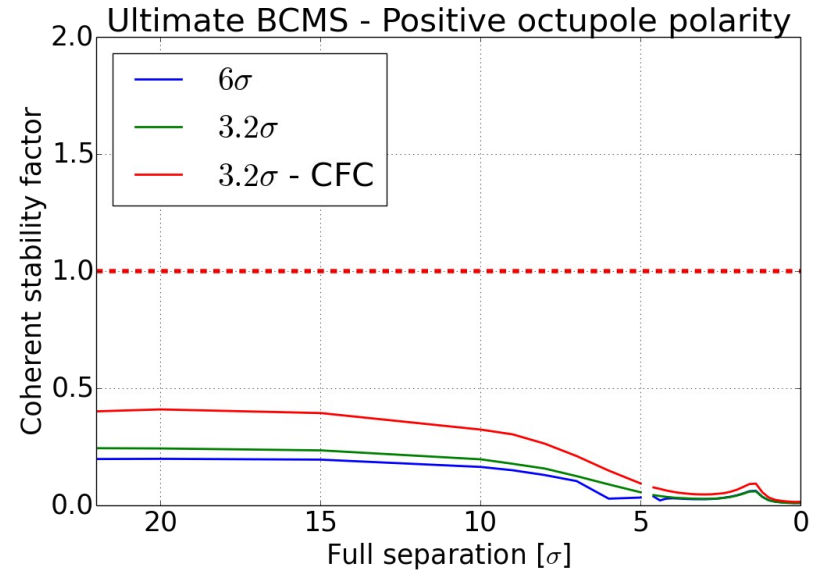
Ramp and ATS



- The beneficial impact of the ATS on the stability margins can be fully exploited by anticipating the telescopic part at the earliest stage, i.e. during the ramp
 - Significant improvement of the stability margin

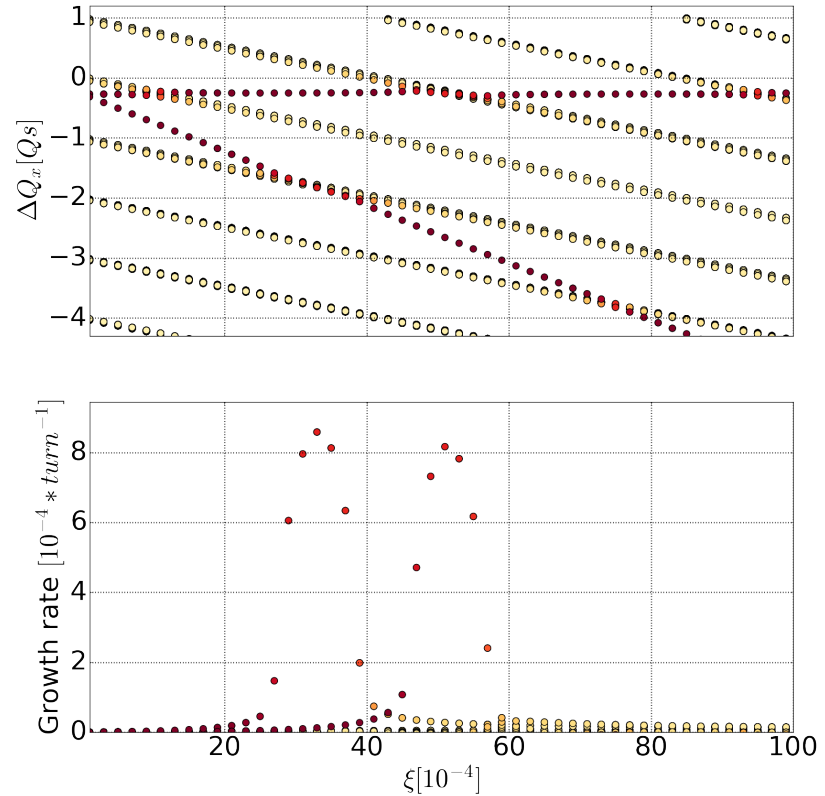
Positive octupole polarity

- The positive octupole polarity also offers improved margins, thanks to the **favourable** interplay of the octupole and the long-range beam-beam interaction
 - The same interplay is **unfavourable** for the dynamic aperture
 - A change of sign once in collision may compromise the stability of non-colliding bunches



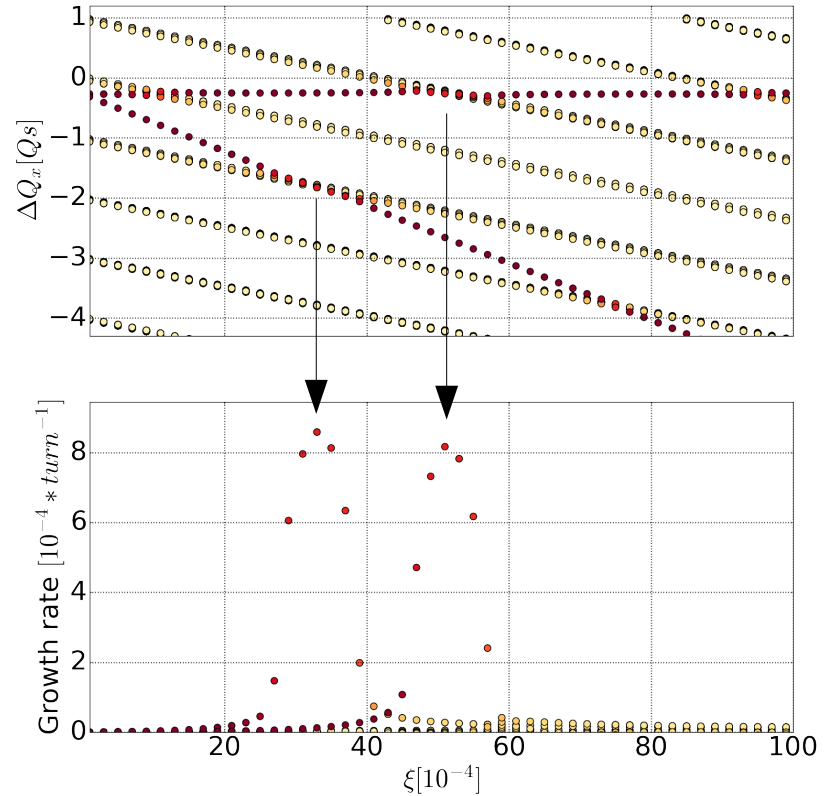
The mode coupling instability of colliding beams

- Beam-beam interactions combined with the impedance leads to a coupling instability similar to the TMCI



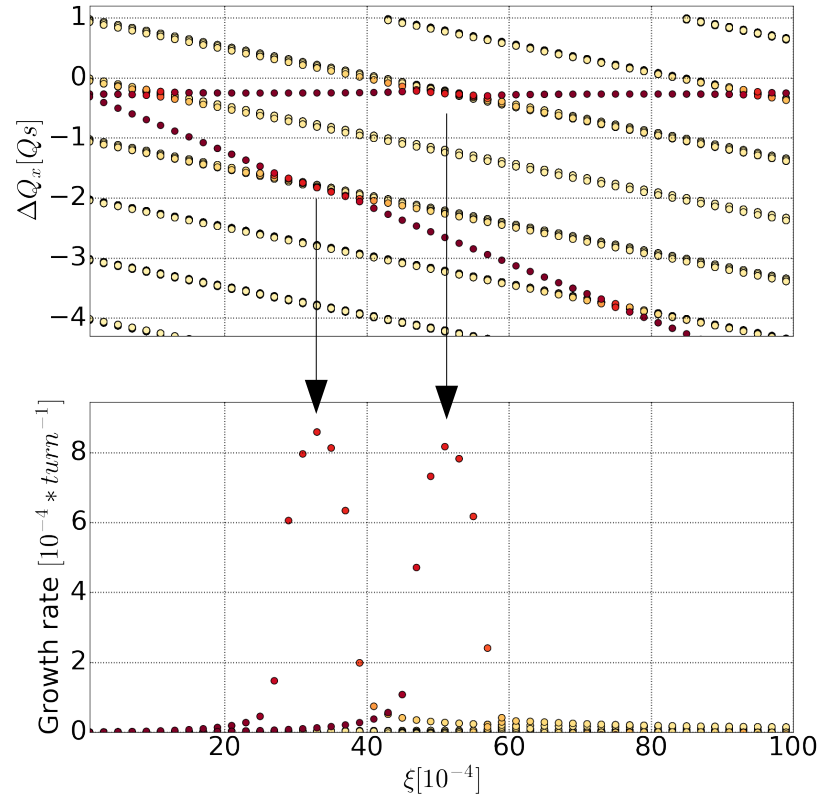
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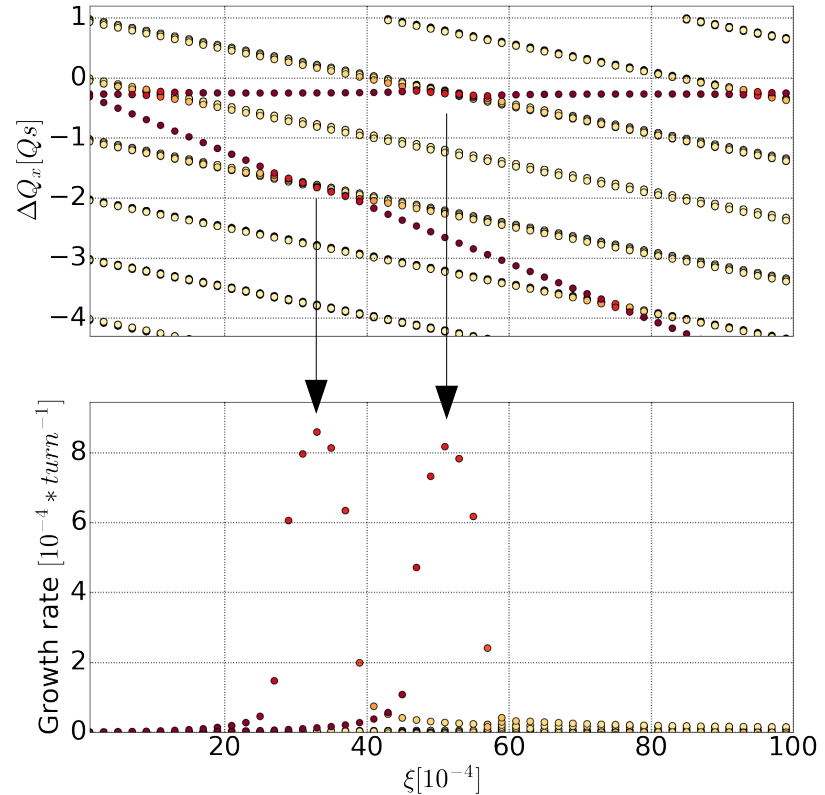
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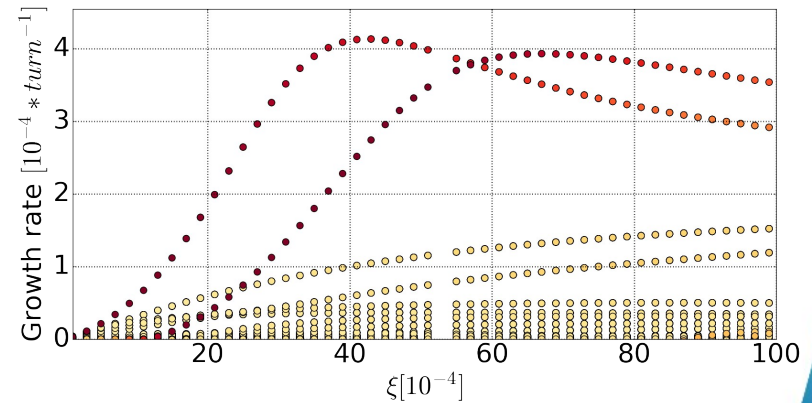
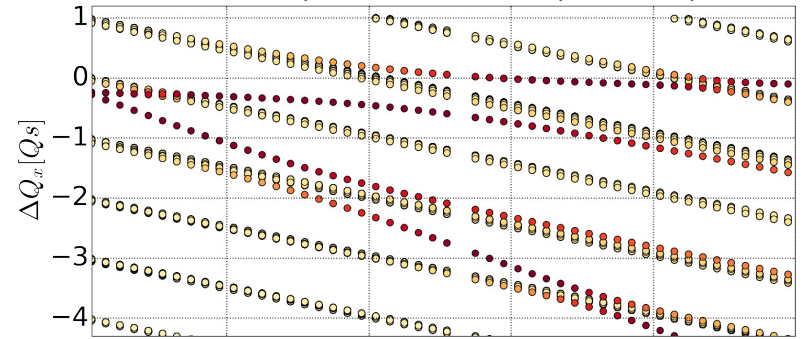
- Beam-beam interactions combined with the impedance leads to a coupling instability similar to the TMCI
 - The feedback is needed to stabilise this instability in collision*
- What happens in the presence of strong hourglass effect (baseline) or large crossing angle (alternative scenario) ?



The mode coupling instability of colliding beams – Hourglass effect

- In the presence of synchrotron coupling (hourglass, crossing angle), instabilities occur at all beam-beam parameters
 - Higher order head-tail modes are also excited

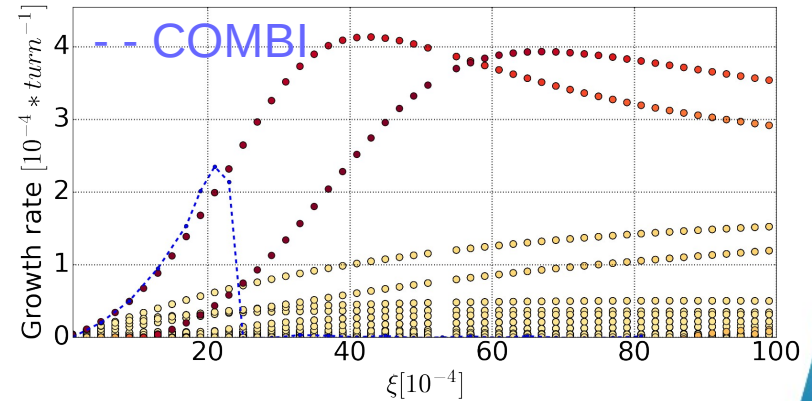
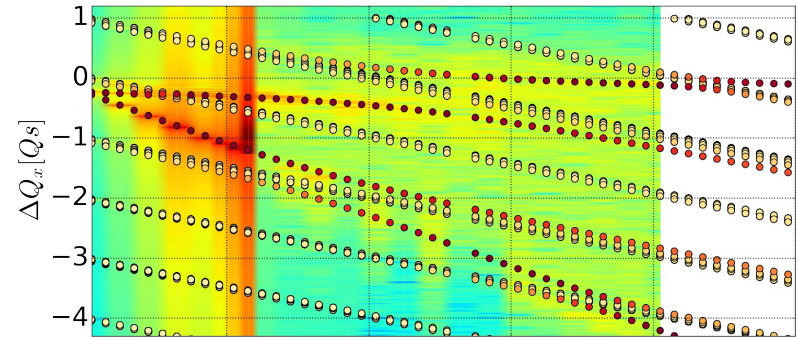
L. Barraud, Master Thesis, UPMC, Paris



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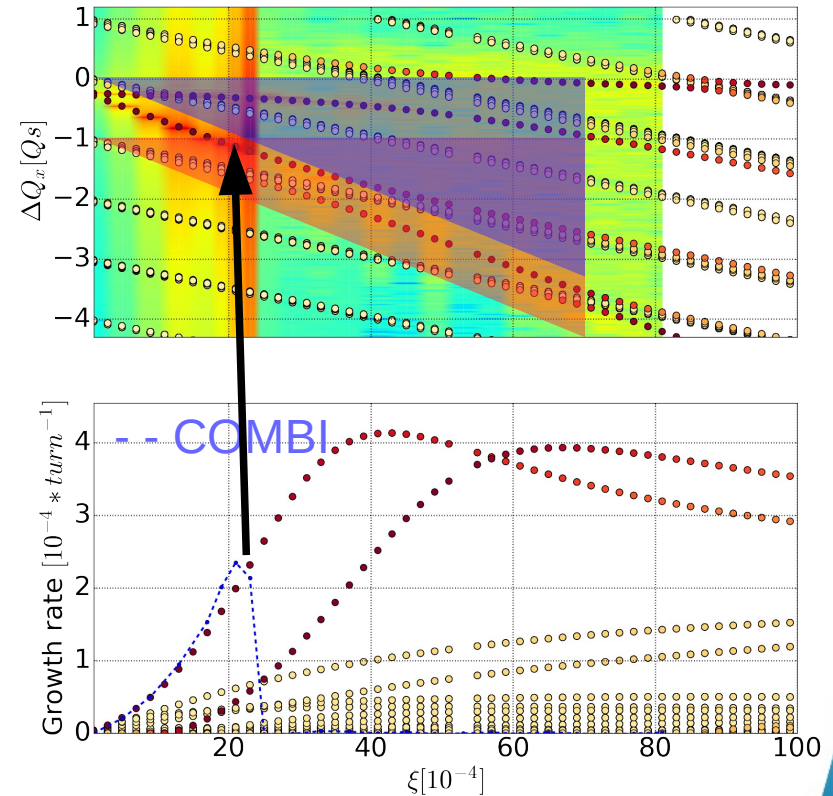


The mode coupling instability of colliding beams – Hourglass effect

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- For the baseline parameters, Landau damping due to the non-linearity of the beam-beam interaction sufficient to stabilise the instability on a wide operating range

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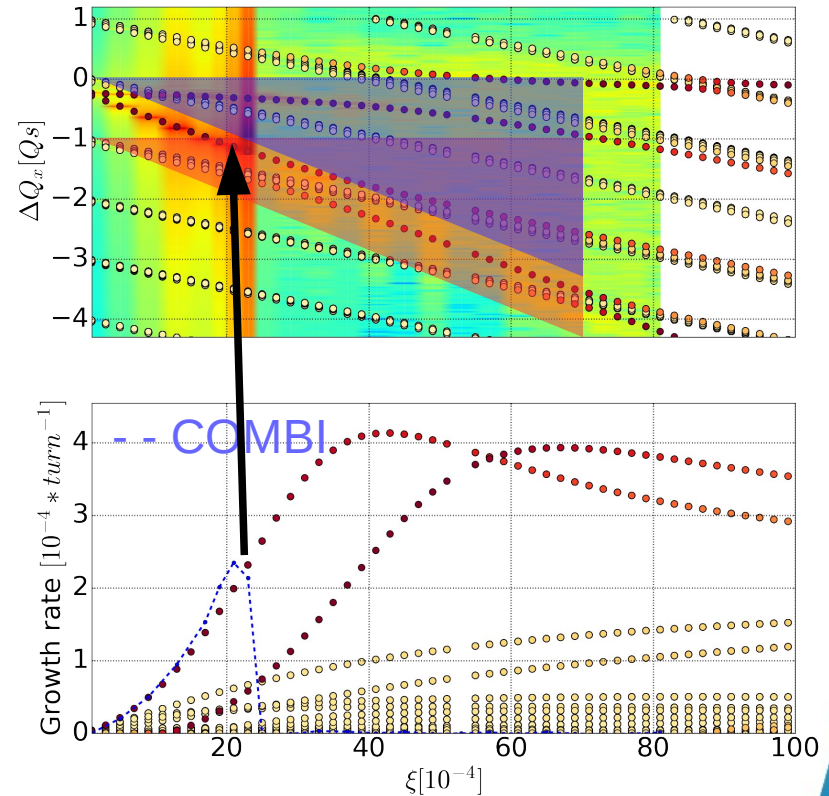


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- Higher order head-tail modes are also excited
- For the baseline parameters, Landau damping due to the non-linearity of the beam-beam interaction sufficient to stabilise the instability on a wide operating range
- For alternative scenarios with a large crossing angle, the effectiveness of the ADT and of Landau damping needs to be assessed

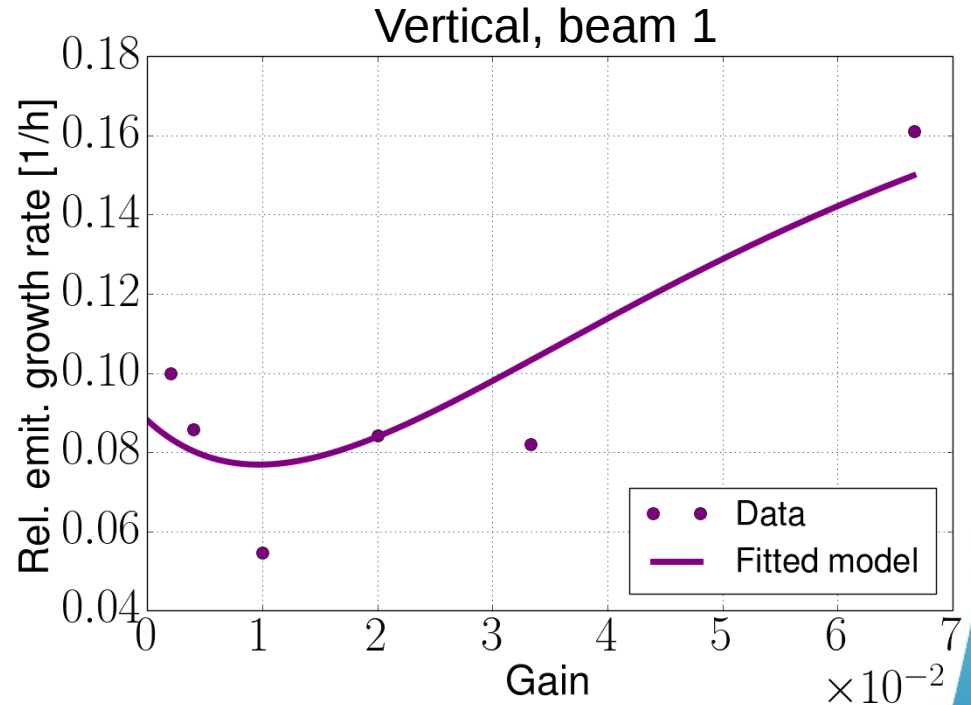
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Noise on colliding beams – ADT and machine noise floor

- The validity of the emittance growth model was verified in MDs in 2016*

$$\frac{1}{\epsilon} \frac{d\epsilon}{dt} = \frac{1}{2} (\delta_0^2 + G^2 \delta_{BPM}^2) \left\langle \frac{4\pi^2 (1 - \frac{G}{2})^2 \Delta Q^2}{4\pi^2 (1 - \frac{G}{2}) \Delta Q^2 + (\frac{G}{2})^2} \right\rangle$$

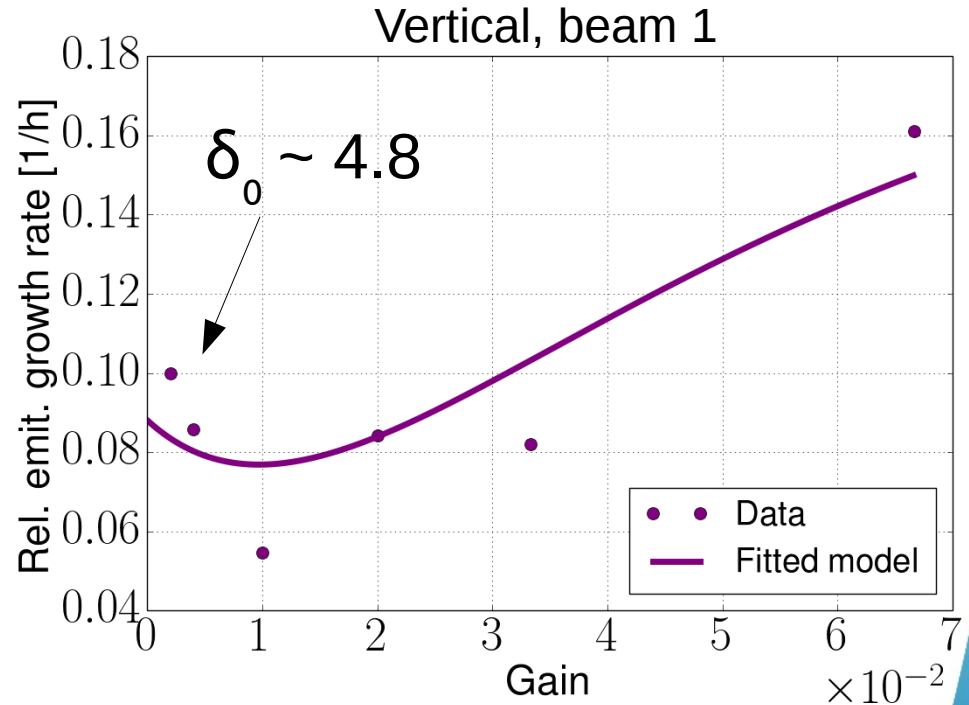


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- This year the noise floor of the ADT and of the machine was measured through the resulting emittance growth

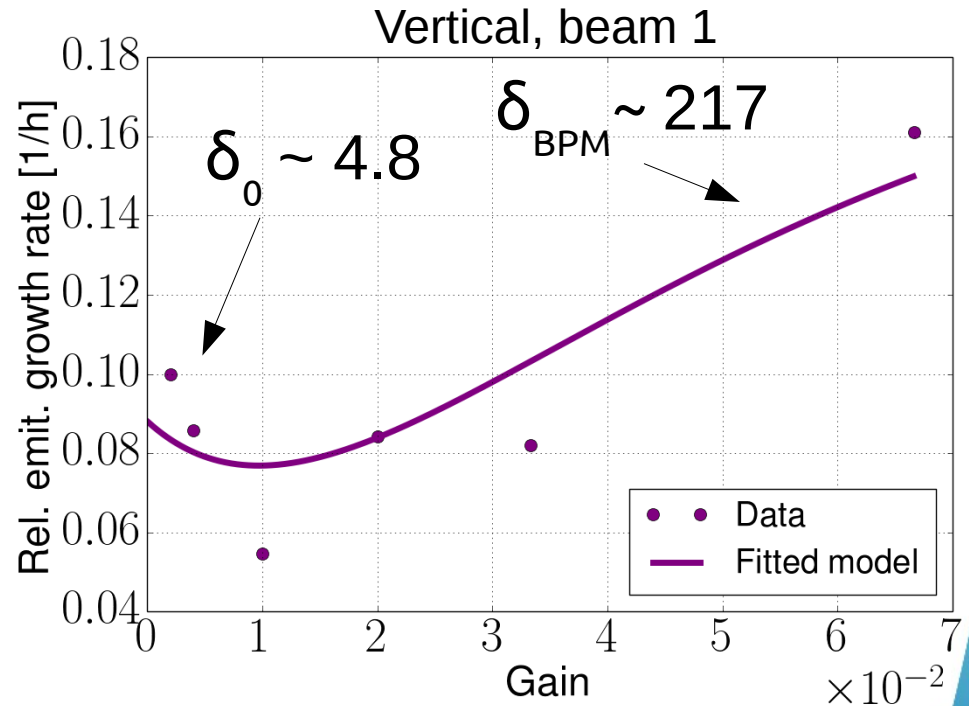


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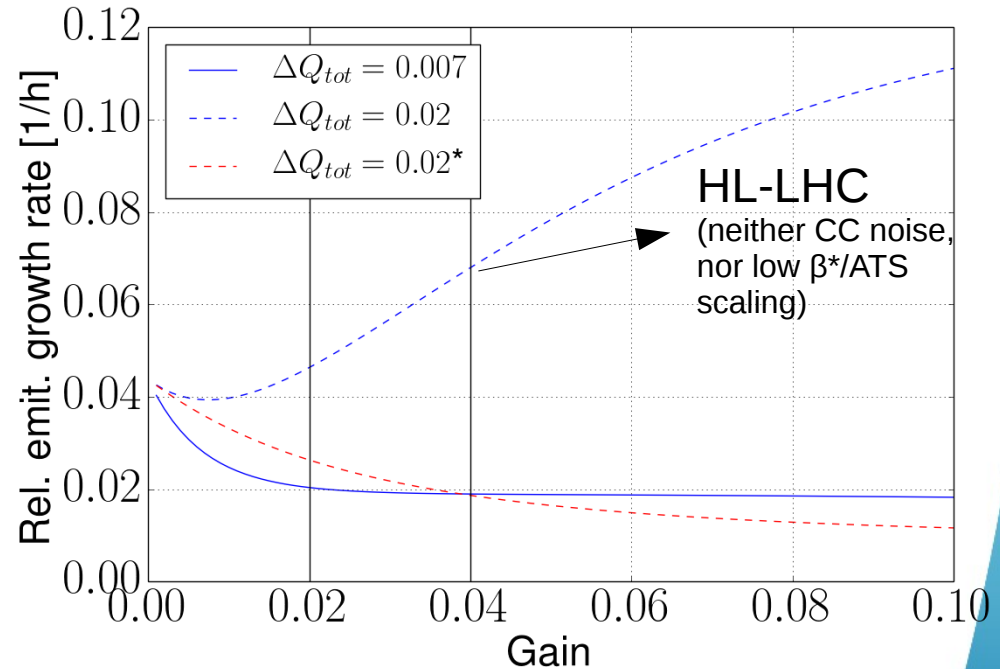
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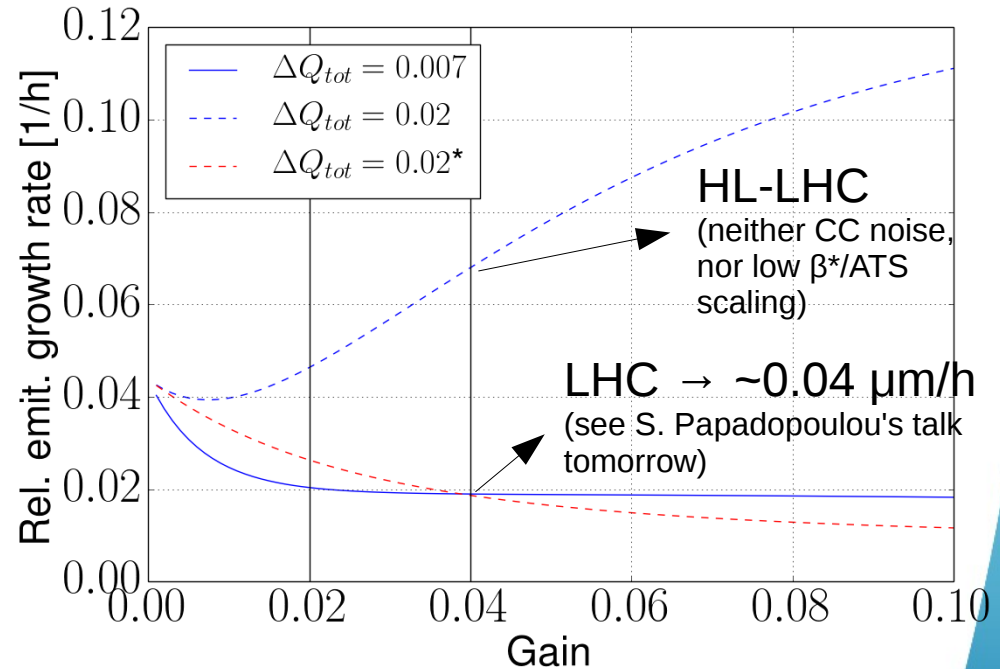
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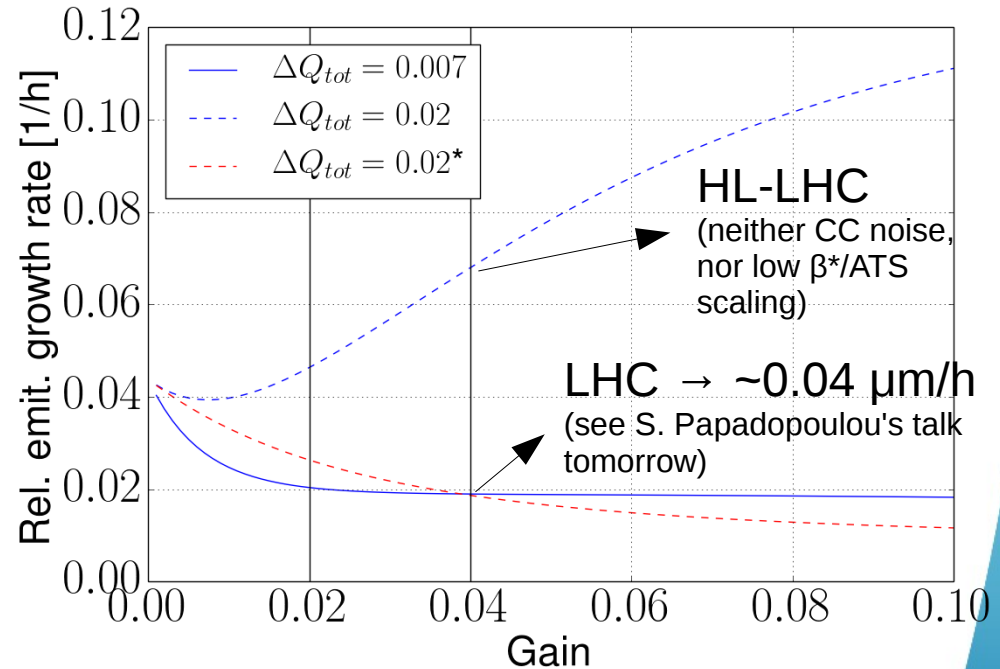
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→ An improvement of the ADT pickup noise floor is needed to recover a tolerable growth

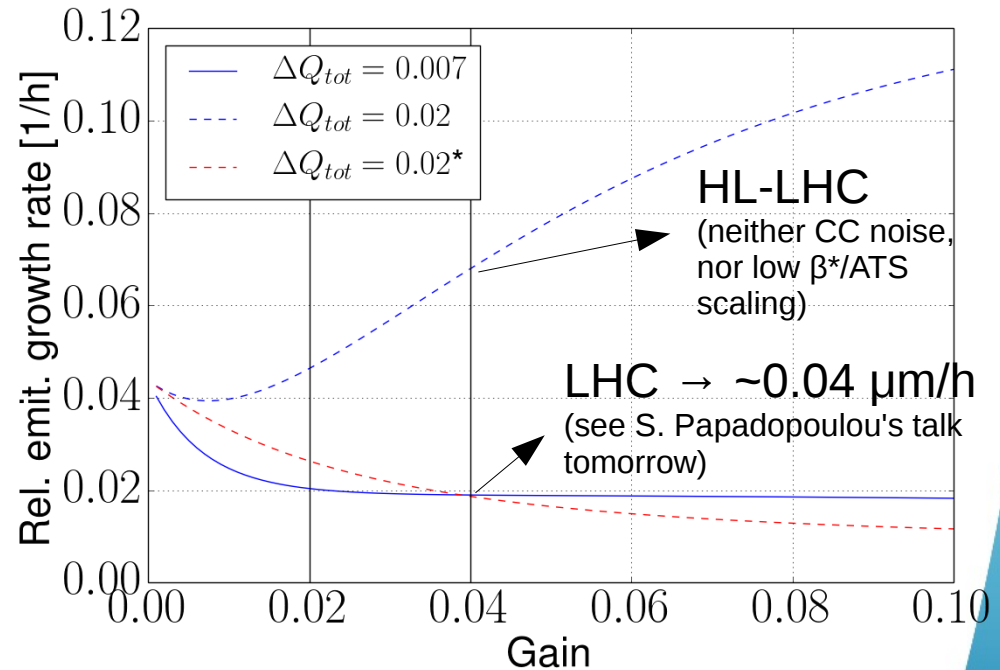


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→ Need to determine how the machine noise scales for HL-LHC (new PCs, low β^* , ATS and new sources)



Conclusion

- Thanks to β^* levelling, the baseline scenario does not suffer significantly from the destructive interplay of long-range beam-beam interactions and the Landau octupoles
- The ultimate configuration is critical from the point of view of beam stability (Under pessimistic assumptions)
 - RATS
 - Positive octupole polarity
 - Reduce further the impedance
- Higher order mode coupling instability of colliding beams is expected in the presence of hourglass / crossing angle
 - Most critical for alternative scenarios, detailed studies ongoing
- The emittance growth due to external sources of noise would be critical in absence of a strong low-noise ADT
 - Experimental studies are needed to identify the sources, allowing for extrapolations to HL-LHC

BACKUP

Noise on colliding beams – Weak-strong vs. Strong-strong

